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(54) A METHOD FOR THE DETECTION OF A DISABLE TONE SIGNAL OF AN ECHO CANCELLER

VERFAHREN ZUM DETEKTIEREN EINES DISABLE-TONSIGNALS EINES ECHOKOMPENSATORS

PROCEDE DE DETECTION CONCERNANT LE SIGNAL DE TONALITE DE NEUTRALISATION DANS UN SUPPRESSEUR D'ECHO

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(56) References cited:
US-A- 4 658 420 **US-A- 5 029 204**

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Description

Field of the Invention

The invention relates to a method for the detection of a disable tone signal in an echo canceller, said disable tone signal being within a predetermined tolerance range from a nominal frequency and including phase inversions occurring at predetermined intervals.

Background of the Invention

End-to-end connections of a data transmission system, such as a telephone network, often show long transit time delays, in consequence of which echo is observed for instance in the case of normal speech, when a signal is reflected from the far end of a connection back to the talker. An echo canceller is an analog or digital device for processing a signal, such as a speech signal, so as to reduce echo by subtracting estimated echo from the echo (signal).

Normally, an echo canceller shall be capable of detecting a so-called disable signal. Upon detecting the disable tone, the echo canceller is switched to a "transparent" state, in which the echo canceller does not process a signal passing through. The characteristics of the disable tone are defined accurately in CCITT recommendation V.25. A disable tone is a signal of about 2100 Hz with phase inversions at intervals of (450 ± 25) ms. The disable tone detection of the echo canceller shall respond to this particular signal but not e.g. to speech or a 2100 Hz signal with no phase inversions. Disable tones are monitored both at the receiving and transmitting end of each telephone channel. Prior art echo cancellers with disable tone detection are disclosed e.g. in U.S. Patents 4,658,420 and 5,029,204.

US-A-4,658,420 describes a method for the detection of a disable tone signal in an echo canceller, said disable tone signal being within a predetermined tolerance range from a nominal frequency and including phase inversions occurring at predetermined intervals, comprising:

a) removing frequencies from an input signal by filtering;
b) creating a substantially in-phase version of said filtered signal;
c) delaying said in-phase version; and
d) detecting a phase inversion in said disable tone signal by means of a logical XOR operation executed on said in-phase version of said filtered signal and the delayed version thereof.

Disclosure of the Invention

The object of the invention is a method for the detection of a disable tone signal in an echo canceller.

This is achieved by means of the method of the invention, which is characterized in that said step of removing frequencies from an input signal by filtering comprises removing frequencies outside said tolerance range from the input signal by band-pass filtering; in that the method further comprises sampling the band-pass filtered signal at a sampling frequency, said sampling frequency being about half of said nominal frequency, the resulting sample signal component being aliased to the vicinity of a zero frequency; and in that said step of creating a substantially in-phase version of said filtered signal comprises creating a substantially in-phase version for said aliased sample signal component; said step of delaying said in-phase version comprises delaying said in-phase version for said aliased sample signal component by about 2n sample signal periods, where n is a positive integer, and said step of detecting a phase inversion in said disable tone signal comprises detecting a phase inversion in said disable tone signal by means of a logical XOR operation executed on said aliased sample signal component and the delayed version thereof.

According to the invention all frequencies falling outside a monitored frequency band are removed from a received signal by band-pass filtering. After this, the tendency of a signal of being aliased to lower frequencies, when the sampling frequency is lower than the Nyquist frequency, is utilized for the detection of a disable tone. To this end, the filtered signal is sampled at a sampling frequency which is only about half of the nominal frequency of the disable tone, resulting in an aliased sample signal component close to the zero frequency. When the sample rate of the original signal is for instance 8000 samples/second (PCM signal) and the sampling frequency is 1000 Hz, then only every eighth original sample signal transmitted in the telephone channel is further processed. Thanks to this solution, a signal processor or another device applying the method of the invention is capable of processing both signal directions in several telephone channels.

When a signal at the preset frequency and on a preset level is detected, the signal is tested in order to find a phase inversion of about 180 degrees. This takes place by means of an XOR operation executed between the aliased sample signal component and the version thereof delayed by two sample signal periods. In-phase signals always have like signs (plus or minus), but if there exists a phase inversion in the disable tone, the original sample signal component and the delayed version thereof have temporarily unlike signs.

By means of the method of the invention, it is possible to provide a very simple disable tone detection requiring a short processing time.

Brief Description of the Drawings

The invention will be explained in the following in greater detail by means of illustrative embodiments referring to the enclosed drawings, in which

Figure 1 shows a block diagram of an echo canceller according to the invention,

Figure 2 shows a graph illustrating frequency characteristics of a disable tone detector, the vertical axis representing the signal level and the horizontal axis the frequency,

Figure 3 illustrates an aliasing in a frequency domain due to the sampling, and

Figures 4A to 4C are signal diagrams illustrating the XOR operation to be used for the detection.

Detailed Description of the Invention

Figure 1 shows a digital echo canceller, to which the inventive detection of a disable tone signal can be applied. The echo canceller comprises an input port S_{in} and an output port S_{out} of a digital signal to be transmitted as well as an input port R_{in} and an output port R_{out} of a digital signal to be received. The echo canceller shall eliminate the echo only in the transmission direction, in this application called far end (the echo canceller can alternatively be constructed to eliminate the echo in the receiving direction). The opposite direction is called near end. The ports S_{in} and R_{out} are connected to the transmission path of the near end and the ports S_{out} and R_{in} to the transmission path of the far end. The echo to be cancelled is a component r(i) of a speech signal x(i) received at the port R_{in} from the far end and transmitted forward over the port Rout to the near end (to the echo path), which component is reflected from the near end.

A transmission signal y(i) of the near end is linearized by an A-law converter 35A, processed by means of an adaptive FIR filter 21 and finally applied to a change-over switch SW1. The switch SW1 controlled by a control unit 26 connects the output of the filter 21 either over a non-linear processor 27 or an A-law converter 36 to the output port S_{out} of the echo canceller.

The adaptive digital filter 21 is for instance a digital transversal filter, which models an impulse response of the echo path. A control unit 22 controls the operation, adaptation and updating of the adaptive filter 21 on the basis of the levels of the signals y(i) and x(i), which levels are obtained by means of level detectors 24 and 25, respectively, and on the basis of an enable tone detection, which is performed by means of an enable tone detection circuitry 37.

The signal x(i) is linearized by A-law converters 35B, 35C and 35D, before being applied to a sample buffer 23, the level detector 25 and the enable tone detection circuitry 37, respectively. Samples taken from the signal x(i) are stored in the sample buffer 23, from which they are applied, if needed, to the filter 21 for the calculation of a correlation between them and samples taken from the signal y(i). Coefficients a_k of the filter 21 are updated on the basis of this correlation.

In the echo canceller shown in Figure 1, the detection of a disable tone is performed by means of the circuitry 37. Firstly, the signal y(i) received from the converter 35A and/or the signal x(i) received from the converter 35D is applied over a change-over switch SW2 to a band-pass filter 33, having a center-frequency of about 2100 Hz and a pass-band of for instance about 1900 to 2350 Hz, at least about 2079 to 2121 Hz. The filter 33 removes all the other frequencies except the ones within the frequency band to be examined. The frequency band required for the detector 37 is illustrated in Figure 2.

From Figure 2 is seen that the detection always shall succeed at frequencies 2100±21 Hz (zone 10) of the disable tone signal, while the operation at frequencies 1900 to 2350 Hz (zone 11) is undefined, i.e. the detection may work, but it does not need to work. Outside the frequency range 1900 to 2350 Hz (zone 12) the detection must not work.

The level of the output signal (i.e. enable tone signal) of the filter 33 is measured by a level detector 32. The input signal of the filter 33 is also applied to a band stop filter 31, the stop band of which is substantially the same as the pass band of the filter 33 and which removes the 1900 to 2350 Hz detection band from the input signal and leaves a surrounding guard band for the level detection by means of a level detector 30. The power level of the guard band is measured in order that the speech cannot be misinterpreted as a disable tone. Again according to Figure 2, when white noise (300 to 3400 Hz) is applied to the detection circuitry 37 simultaneously with a 2100 Hz signal having a level of -31 dBmO, the white noise shall prevent the detection, if the noise level rises close to the level of the 2100 Hz signal. When the level of the disable tone signal is raised, the white noise shall prevent a switching off of the echo canceller within the whole frequency range on levels lower than the disable tone level.

When the control unit 22 detects a signal at the preset frequency and on a preset level on the basis of the outputs of the level detectors 30 and 32, the signal is tested to find a phase inversion of 180±25 degrees in the signal. For this purpose, the output signal of the filter 33 is applied also to a phase inversion detector 34. Firstly, the phase inversion detector 34 samples the signal at a sampling frequency which is about half of the 2100 Hz tone frequency. In the preferred embodiment of the invention the sampling frequency is 1000 Hz. As illustrated in Figure 3, an aliased sample signal component 40' results in the vicinity of the zero frequency in consequence of sampling an original signal 40 having a frequency, of about 2100 Hz. Then the detector 34 generates a substantially in-phase component 40" delayed by 2n signal periods, preferably 2 periods, with respect to the sample signal component 40' aliased in the vicinity of the zero frequency, where n is a positive integer, as illustrated in Figures 4A and 4B. Then the detector 34 detects a phase inversion in the disable tone by means of an XOR operation executed between the aliased sample signal component 40' and the delayed version 40" thereof. An XOR operation can for instance be ex-

ecuted on the signs of the signals 40' and 40". When a logic XOR operation is executed on the sample signal component 40' and the delayed version 40", the signals 40' and 40" being substantially in-phase and of the same sign, the result is a logic state 0, as illustrated in Figure 4C. When a phase inversion occurs in the signal 40' at time 41, a corresponding phase inversion does not occur in the delayed version 40" until approximately two periods later at time 41'. Then the XOR operation temporarily gives a logic state 1, because due to the phase inversion 41 in the disable tone signal a phase and sign of the delayed version 40" temporarily differ from those of the original sample signal component 40', as illustrated in Figure 4C. The duration of the temporary change in the result of the XOR operation expresses the amount of the phase change in the disable tone signal.

Before a phase inversion can be detected, a delay shall be searched for for the delayed sample signal component 40", by which delay the delayed sample is located as accurately as possible at the distance of two periods from the respective sample of the original signal. This is carried out by experimenting with all delays between 7 to 20 sampling periods. These delay differences correspond to a 140 to 50 Hz frequency range, to which 2050 to 2140 Hz frequencies are aliased and which thus is at the same time the frequency range within which a signal may be detected, while according to the specifications, frequencies between 2079 and 2121 Hz must be detected. A delay by which the XOR operation yields only one or no result with unlike signs during one signal period will be close to the actual frequency delayed by about one signal period, and the obtained delay can be used as a delay value in the subsequent stages of detection. If the XOR operation always gives a similar result, the signals are in-phase. On the other hand, if the signals are in-phase all the time, they also have the same frequencies.

If a phase inversion occurs when a frequency is searched for, it results in an unsuccessful search in the event that the phase inversion is coincident with finding of the desired frequency. In that case the frequency search procedure restarts from the beginning. At renewal, no phase inversions should be present in the signal, because phase inversions shall occur at intervals of (450±30) ms and a search lasts about 100 ms at the most. The maximum detection time of a phase inversion is thus (2*100ms)+480ms = 680ms.

In the preferred embodiment of the invention all the blocks shown in Figure 1 are realized by software in a digital signal processor.

The invention has above been described in connection with particular exemplifying echo canceller types and digital transversal filters. The method of the invention can, however, be applied to all echo cancellers.

The figures and the description relating to them are only intended to illustrate the present invention, anyway. As to the details, the method of the invention can vary within the scope of the enclosed claims.

Claims

1. A method for the detection of a disable tone signal in an echo canceller, said disable tone signal being within a predetermined tolerance range from a nominal frequency and including phase inversions occurring at predetermined intervals, comprising:

   a) removing frequencies from an input signal by filtering;
   b) creating a substantially in-phase version of said filtered signal;
   c) delaying said in-phase version; and
   d) detecting a phase inversion in said disable tone signal by means of a logical XOR operation executed on said in-phase version of said filtered signal and the delayed version thereof;
   characterised in that

   said step of removing frequencies from an input signal by filtering comprises removing frequencies outside said tolerance range from the input signal by band-pass filtering (33); in that the method further comprises
   sampling (34) the band-pass filtered signal at a sampling frequency, said sampling frequency being about half of said nominal frequency, the resulting sample signal component (40') being aliased to the vicinity of a zero frequency; and in that
   said step of creating a substantially in-phase version of said filtered signal comprises creating a substantially in-phase version for said aliased sample signal component;
   said step of delaying said in-phase version comprises delaying said in-phase version for said aliased sample signal component by about 2n sample signal periods, where n is a positive integer, and
   said step of detecting a phase inversion in said disable tone signal comprises detecting a phase inversion in said disable tone signal by means of a logical XOR operation executed on said aliased sample signal component and the delayed version thereof.

2. A method according to claim 1, characterised in that the logical XOR operation results in a first logical state, when said sample signal component and said delayed version are substantially in-phase and of the same sign, and in a second logical state, when the delayed version has temporarily, in consequence of a phase inversion occurring in said disable tone signal, a phase and sign unlike those of the sample signal component, and that the phase inversion is detected on the basis of said temporary change in the result yielded by the XOR operation.

3. A method according to claim 2, **characterized** in that the duration of said temporary change in the result yielded by the XOR operation expresses the amount of the phase change in the disable tone signal.

4. A method according to claim 1, 2 or 3, **characterized** in that the delay for delaying said sample signal component by about 2n periods is searched for before the detection of the phase inversion, said search comprising testing with a suitable number of delays, each of which delays affecting a delay of about 2 signal periods for one of the frequency components aliased to the vicinity of the zero frequency, and selecting the delay by which the XOR operation executed on said sample signal component and said delayed version thereof gives only one or no result indicating the unlike phases of the signals during one period of the sample signal.

5. A method according to any of the preceding claims, **characterized** in that said nominal frequency is 2100 Hz, said tolerance range is 2079 to 2121 Hz, the sampling frequency is 1000 Hz, the frequency to which said nominal frequenzy aliases in the vicinity of the zero frequency being 100 Hz and the frequency range to which the tolerance range aliases in the vicinity of the zero frequency being 140 to 50 Hz.

6. A method according to claim 5, **characterized** in that delays between 7 and 20 sampling periods are tested in the delay search.

7. A method according to any of the preceding claims, **characterized** in that a phase inversion of about 155 to 205 degrees occurs in the disable tone signal at intervals of about 420 to 480 ms.

Patentansprüche

1. Verfahren zum Erfassen eines Abschaltetonsignals in einem Echolöscher, wobei das Abschaltetonsignal innerhalb eines vorbestimmten Toleranzbereiches einer Nennfrequenz liegt und Phasenumkehrungen enthält, die in vorbestimmten Intervallen auftreten, mit den folgenden Schritten:

   a) Entfernen von Frequenzen von einem Eingangssignal durch Filtern;

   b) Schaffen einer im wesentlichen phasengleichen Version des gefilterten Signals;

   c) Verzögern der phasengleichen Version; und

   d) Erfassen einer Phasenumkehrung in dem Abschaltetonsignal mittels einer logischen Exklusiv-ODER-Operation, die an der phasengleichen Version des gefilterten Signals und seiner verzögerten Version ausgeführt wird;

   dadurch gekennzeichnet,

   daß der Schritt des Entfernens von Frequenzen von einem Eingangssignal durch Filtern das Entfernen von Frequenzen außerhalb des Toleranzbereichs von dem Eingangssignal durch Bandpaßfilterung (33) aufweist;

   daß das Verfahren ferner

   das Abtasten (34) des bandpaßgefilterten Signals bei einer Abtastfrequenz aufweist, wobei die Abtastfrequenz etwa die Hälfte der Nennfrequenz beträgt, wobei die resultierende Abtastsignalkomponente (40') einer Aliasbehandlung in die Nähe einer Nullfrequenz unterzogen wird; und

   daß der Schritt des Schaffens einer im wesentlichen phasengleichen Version des gefilterten Signals das Schaffen einer im wesentlichen phasengleichen Version für die aliasbehandelte Abtastsignalkomponente aufweist;

   wobei der Schritt des Verzögerns der phasengleichen Version das Verzögern der phasengleichen Version der aliasbehandelten Abtastsignalkomponente um etwa 2n Abtastsignalperioden aufweist, wobei n eine positive ganze Zahl ist, und

   wobei der Schritt des Erfassens einer Phasenumkehrung in dem Abschaltetonsignal das Erfassen einer Phasenumkehrung in dem Abschaltetonsignal mittels einer logischen Exklusiv-ODER-Operation aufweist, die an der aliasbehandelten Abtastsignalkomponente und deren verzögerter Version ausgeführt wird.

2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß die logische Exklusiv-ODER-Operation in einem ersten logischen Zustand resultiert, wenn die Abtastsignalkomponente und die verzögerte Version im wesentlichen phasengleich sind und dasselbe Vorzeichen haben, und in einem zweiten logischen Zustand, wenn die verzögerte Version als Folge einer in dem Abschaltetonsignal auftretenden Phasenumkehrung vorübergehend eine Phase und ein Vorzeichen hat, die von denjenigen der Abtastsignalkomponente verschieden sind, und daß die Phasenumkehrung auf der Basis der vorübergehenden Veränderung des Resultats erfaßt wird, das die Exklusiv-ODER-Operation ergibt.

3. Verfahren nach Anspruch 2, dadurch gekennzeichnet, daß die Dauer der vorübergehenden Änderung des Resultats der Exklusiv-ODER-Operation das Ausmaß der Phasenänderung in dem Abschaltetonsignal ausdrückt.

4. Verfahren nach Anspruch 1, 2 oder 3, dadurch gekennzeichnet, daß nach der Verzögerung zum Verzögern der Abtastsignalkomponente um etwa 2n Perioden vor dem Erfassen der Phasenumkehrung gesucht wird, wobei die Suche ein Testen mit einer geeigneten Anzahl von Verzögerungen aufweist, von welchen jede eine Verzögerung von etwa zwei Signalperioden für eine der Frequenzkomponenten bewirkt, die in die Nähe der Nullfrequenz aliasbehandelt wurden, und ein Auswählen der Verzögerung, durch die die an der Abtastsignalkomponente und deren verzögerter Version ausgeführte Exklusiv-ODER-Operation nur ein oder kein Resultat ergibt, das die ungleichen Phasen der Signale während einer Periode des Abtastsignals anzeigt.

5. Verfahren nach einem der vorstehenden Ansprüche, dadurch gekennzeichnet, daß die Nennfrequenz 2100 Hz ist, der Toleranzbereich 2079 bis 2121 Hz ist, die Abtastfrequenz 1000 Hz ist, die Frequenz, zu der die Nennfrequenz in die Nähe der Nullfrequenz aliasbehandelt wird, 100 Hz ist und der Frequenzbereich, zu dem der Toleranzbereich in die Nähe der Nullfrequenz aliasbehandelt wird, 140 bis 50 Hz ist.

6. Verfahren nach Anspruch 5, dadurch gekennzeichnet, daß Verzögerungen zwischen 7 und 20 Abtastperioden bei der Verzögerungssuche getestet werden.

7. Verfahren nach einem der vorstehenden Ansprüche, dadurch gekennzeichnet, daß eine Phasenumkehrung von etwa 155 bis 205 Grad in dem Abschaltetonsignal bei Intervallen von etwa 420 bis 480 ms auftritt.

Revendications

1. Procédé de détection d'un signal de tonalité de neutralisation dans un suppresseur d'écho, ledit signal de tonalité de neutralisation étant situé dans une fourchette de tolérances prédéterminée par rapport à une fréquence nominale, et comprenant des inversions de phase se produisant à des intervalles prédéterminés, ledit procédé comprenant :

   a) l'élimination par filtrage de fréquences d'un signal d'entrée ;
   b) la création d'une version sensiblement en phase dudit signal filtré ;
   c) le retardement de cette version en phase ; et
   d) la détection d'une inversion de phase dans ledit signal de tonalité de neutralisation, au moyen d'une opération logique OU exclusif exécutée sur la version en phase du signal filtré et sur sa version retardée ;

   caractérisé en ce que :

   ladite étape d'élimination par filtrage de fréquences d'un signal d'entrée comprend l'élimination de fréquences situées à l'extérieur de la fourchette de tolérances du signal d'entrée, au moyen d'un filtrage passe-bande (33) ;
   en ce que le procédé comprend en outre :
   l'échantillonnage (34) du signal traité par filtrage passe-bande, à une fréquence d'échantillonnage, ladite fréquence d'échantillonnage étant sensiblement la moitié de la fréquence nominale, la composante (40') résultante du signal échantillonné étant repliée au voisinage d'une fréquence zéro,
   et en ce que ;
   ladite étape de création d'une version sensiblement en phase dudit signal filtré comprend la création d'une version sensiblement en phase de ladite composante de signal échantillonné repliée ;
   ladite étape de retardement de la version en phase comprend le retardement de la version en phase de la composante de signal échantillonné repliée, d'une valeur d'environ 2n périodes de signal échantillonné, n étant un nombre entier positif ;
   ladite étape de détection d'une inversion de phase dans le signal de tonalité de neutralisation comprend la détection d'une inversion de phase dans le signal de tonalité de neutralisation au moyen d'une opération logique OU exclusif exécutée sur ladite composante de signal d'échantillonnage et sur sa version retardée.

2. Procédé selon la revendication 1, caractérisé en ce que l'opération logique OU exclusif produit un premier état logique, lorsque ladite composante de signal échantillonnée et ladite version retardée sont sensiblement en phase et du même signe, et un deuxième état logique, lorsque, suite à une inversion de phase se produisant dans le signal de tonalité de neutralisation, la phase et le signe de la version retardée sont différents de ceux de la composante de signal d'échantillonnage, et en ce que l'inversion de phase est détectée sur la base du changement temporaire du résultat de l'opération OU exclusif.

3. Procédé selon la revendication 2, caractérisé en ce que la durée dudit changement

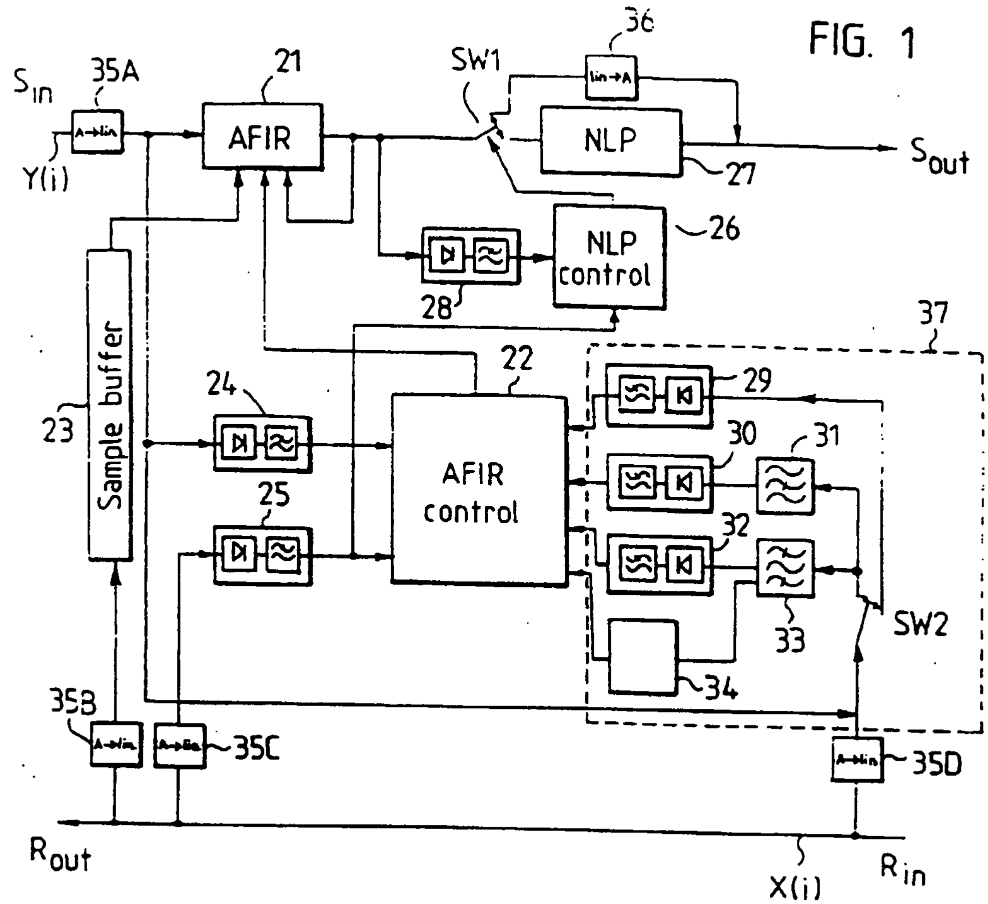
temporaire du résultat de l'opération OU exclusif exprime la valeur du changement de phase du signal de tonalité de neutralisation.

4. Procédé selon la revendication 1, 2 ou 3, caractérisé en ce que le retard pour retarder ladite composante de signal échantillonnée d'environ 2n périodes est recherché avant la détection de l'inversion de phase, ladite recherche comprenant des tests avec un nombre approprié de retards, chacun de ces retards concernant un retard d'environ 2 périodes de signal pour l'une des composantes de fréquence repliées au voisinage de la fréquence zéro, et la sélection du retard grâce auquel l'opération OU exclusif exécutée sur ladite composante de signal échantillonnée et sa version retardée ne produit qu'un seul résultat ou aucun, indiquant les phases différentes des signaux au cours d'une période du signal échantillonnée.

5. Procédé selon l'une quelconque des revendications précédentes,
caractérisé en ce que ladite fréquence nominale est de 2100 Hz, que la fourchette de tolérances est de 2079 à 2121 Hz, que la fréquence d'échantillonnage est de 1000 Hz, que la fréquence à laquelle la fréquence nominale est repliée au voisinage de la fréquence zéro est de 100 Hz, et que la fourchette de fréquences à laquelle est repliée la fourchette de tolérances au voisinage de la fréquence zéro est de 140 à 50 Hz.

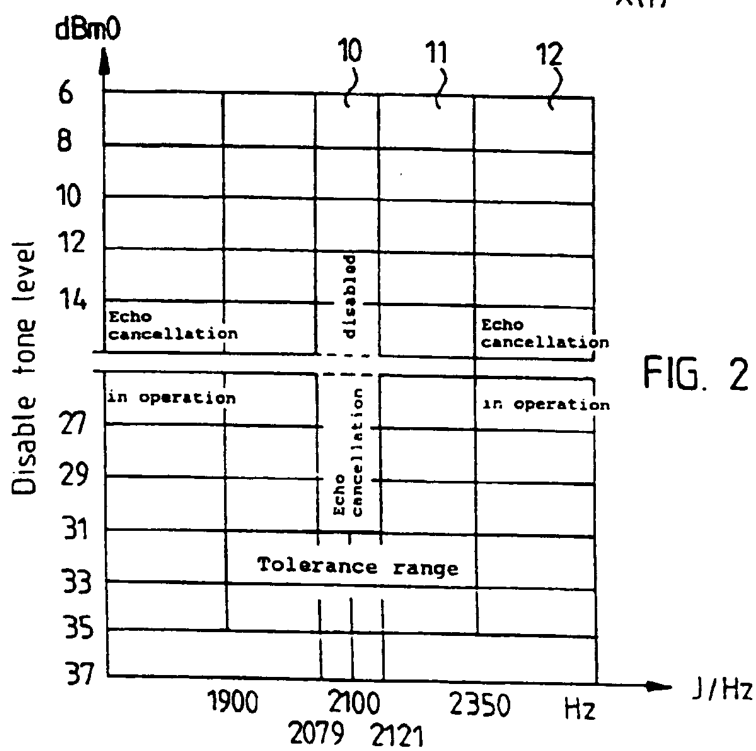
6. Procédé selon la revendication 5,
caractérisé en ce que des retards entre 7 et 20 périodes d'échantillonnage sont testés au cours de la recherche de retard.

7. Procédé selon l'une quelconque des revendications précédentes,
caractérisé en ce qu'une inversion de phase de 155 à 205 degrés se produit dans le signal de tonalité de neutralisation à des intervalles d'environ 420 à 480 ms.



Sin
35A
Y(i)
21
AFIR
SW1
36
lin→A
NLP
27
Sout
26
NLP control
28
37
22
29
30
31
32
33
34
SW2
24
25
AFIR control
23
Sample buffer
35B
A→lin
A→lin
35C
A→lin
35D
Rout
X(i)
Rin

FIG. 1



dBm0
Disable tone level
6
8
10
12
14
27
29
31
33
35
37
10
11
12
Echo cancellation
in operation
disabled
Echo cancellation
Echo cancellation
in operation
Tolerance range
1900
2100
2079
2121
2350
Hz
J/Hz

FIG. 2

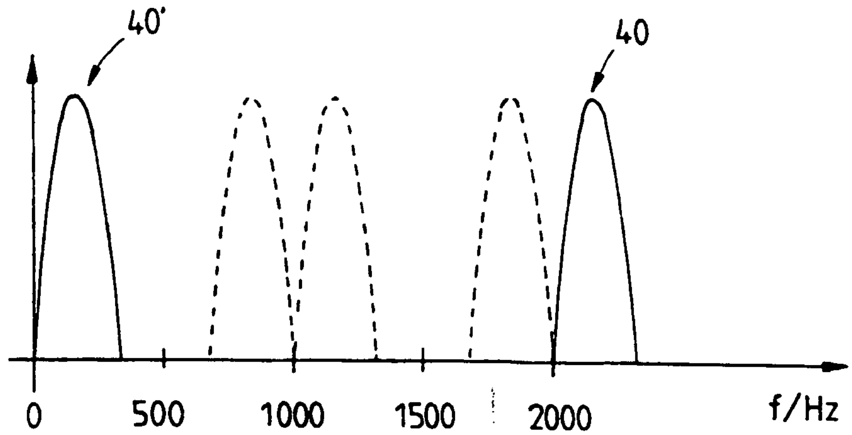


FIG. 3

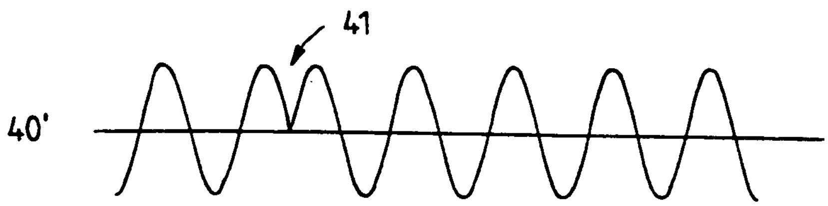


FIG. 4A

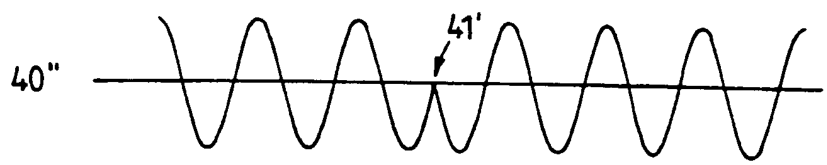


FIG. 4B

FIG. 4C